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Subtropical urban turfs: Carbon and nitrogen pools and the role of enzyme activity

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ABSTRACT

Urban grasslands not only provide a recreational venue for urban residents, but also sequester organic carbon (OC) in vegetation and soils through photosynthesis, and release carbon dioxide through respiration, which largely contribute to carbon storage and fluxes at regional and global scales. We investigated organic carbon and nitrogen pools in subtropical turfs and found that dissolved organic carbon (DOC) and dissolved organic nitrogen (DON) were regulated by several factors including microbial activity which is indicated by soil enzymatic activity. We observed a vertical variation and different temporal patterns in both soil DOC, DON and enzyme activities, which decreased significantly with increasing soil depths. We further found that concentration of soil DON was linked with turf age. There were correlations between grass biomass and soil properties, and soil enzyme activities. In particular, soil bulk density was significantly correlated with soil moisture and soil OC. In addition, DOC correlated significantly with DON. Significant negative correlations were also observed between soil total dissolved nitrogen (TDN) and grass biomass of *Axonopus compressus* and *Zoysia matrella*. Specifically, grass biomass was significantly correlated with the soil activity of urease and β-glucosidase. Soil NO_3-N concentration also showed negative correlations with the activity of both β-glucosidase and protease but no significant correlation between cellulase and soil properties or grass biomass. Our study demonstrated a relationship between soil C and N dynamics and soil enzymes that could be modulated to enhance soil organic C pools through management and maintenance practices.

Introduction

Urban ecosystems are exposed to higher air and soil temperatures than their surroundings due to urban heat island (UHI) effect, and thus are more vulnerable to global warming. One of the consequences of the UHI effect is an increase in respiration rates in urban vegetation and soils due to elevated temperature, which in turn leads to enhanced microbial and soil enzyme activities (Davidson and Janssens, 2006; Karhu et al., 2014). Allison et al. (2010) presented a microbial-enzyme model in which microbial biomass and soil enzymes work together as catalysts in the conversion of soil organic carbon (SOC) to dissolved organic carbon (DOC), which is key step for SOC decomposition. In addition, SOC accounts for more than 60% of the global soil C pool, which is more than three times the size of the atmospheric pool and plays a critical role in the soil C fluxes and the global C cycle (Lal, 2004).

Dissolved organic matter (DOM) plays a critical role in the ecosystems as it mediates many chemical and biological reactions (Chantigny, 2003). DOC refers to all dissolved organic

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C-containing molecules in water or soils (McDowell and Likens, 1988). Despite the fact that DOC accounts for only a small part of the soil C, it is involved in many important soil biological processes and serves as a transfer means for C between ecosystems, regulating the sequestration and export of soil organic C pools. On the other hand, urban ecosystems have lower C inputs than natural ecosystems due to less litter addition, and consequently lower decomposition rate and C release (Churkina, 2012). Therefore, it represents a critical factor in global C cycle.

In addition to DOC, dissolved organic nitrogen (DON) is another major component of the soil microenvironment. DON commonly refers to the organic forms of nitrogen such as polypeptides, free amino acids or other nitrogenous organic materials either excreted by living organisms or released from decomposed life forms (Neff and Asner, 2001; Qualls and Richardson, 2003). In soils, DON is present in two different pools: amino acids and proteins which were readily decomposed by microbes; and high molecular weight DONs that undergo slow turnover (Jones et al., 2004). In ecosystems with little anthropogenic N input, vegetation and hydrology play critical roles in N retention and loss (Cairns and Lajtha, 2005). In general, DON is a major source of N for microorganisms and plants, which in turn contribute to local climate changes by generating as well as absorbing various greenhouse gases. Thus, DON contributes both directly and indirectly to local and global ecosystems. Interactions among microbes, plants and soil control the level of DON and DOC, and affect climate change.

Soil enzymes play a key role in nutrient cycling, which involved many biochemical processes in terms of degradation, transformation and mineralization of soil organic materials (Dick et al., 1996; Sinsabaugh, 2010), thereby contributing to the stock and export of soil DOC and DON pools. On the other hand, soil enzymes have been reported to be sensitive to soil conditions such as moisture, temperature, and field management practices (Bandick and Dick, 1999; Green and Oleksyszyn, 2002) such as tillage (Kandeler et al., 1999b), burning and fertilization (Ajwa et al., 1999).

However, little is known about the role of soil enzymes in regulating the stock and export of soil organic matter in urban ecosystems. Therefore, SOC, DOC, DON, soil respiration, microbial biomass and enzyme pools should be investigated further in urban ecosystems to determine their interactive influences on C cycle at multiple scales in local, regional and global levels. This study assessed (1) DOC and DON exports and their effect on soil C pool in urban turfs; (2) soil enzyme activities and their role in governing soil DOC and DON pools in urban turfs with different grass species in metropolitan Shenzhen and Hong Kong in southern China.

1. Materials and methods

1.1. Site description

We studied selected urban turfs in Hong Kong (22°15′44″N, 114°10′ 41″E) and Shenzhen (22°32′43″N, 114°04′05″E), China. We chose turfs according to the following criteria: (1) turf area larger than 1000 m^2; (2) grass species commonly employed in subtropical cities in China; and (3) different types of turfs with wide turf ages, including lawns (located in urban parks and campus), athletic (football and cricket) fields, green roofs, roadside green belts, which were established from 1957 to 2011 (Table 1).

There were five grass species in the studied turfs. *Axonopus compressus* was found in most turfs in Hong Kong, while *Zoysia matrella* was the dominant species in Shenzhen. *Zoysia japonica*, *Cynodon dactylon* × *C. transvaalensis* and *Lolium perenne* were also grown in sports fields in Hong Kong. We collected soil and grass samples from 14 turfs in Hong Kong and another 14 in Shenzhen (Table 1) during the wet season from 15 August to 27 September 2012.

1.2. Soil sampling and analysis

The sampling followed the methods as described by Kong et al. (2014). We selected 6–18 points based on the size of turf, types of grass species, locations and phases for soil sampling from all the field turfs. Generally, for turfs with one grass species, 9 points were sampled for park size below 10,000 m^2 and 15 points for size above 10,000 m^2. For turfs with more than two grass species, 15 points were sampled. Specifically, 18 points were sampled for turfs located far from each other in the same park, including Sha Tin Park (STP), Kowloon Park (KLP), Yuen Long Park (YLP) and Tai Po Waterfront Park (TPWP).

Soils were sampled from 0 to 5 cm, 5–10 cm and 10–15 cm with a soil corer of 5 cm in diameter and 20 cm in length. Samples were placed in plastic bags and delivered to the laboratory for analysis. Twenty grams of field-moist soils were extracted by 100 mL distilled water and filtered through Whatman No. 1 papers. Soil filtrates were used for the determination of ammonium-N (NH_4-N), nitrate-N (NO_3-N), DON and DOC concentrations. NH_4-N and NO_3-N were determined using a SAN++ Segmented Flow Analyzer (Skalar Analytical B.V., Breda, Netherlands). Total dissolved nitrogen (TDN) was determined using a Shimadzu TOC 5000A Total Organic Carbon Analyzer with a TNM-1 total nitrogen detector. DON was calculated by the difference: DON = TDN – (NO_3 + NH_4). DOC was determined by the TOC 5000A TOC Analyzer. Measurement of soil pH, soil water content, and SOC following the methods as described by Kong et al. (2014). We then performed Pearson Correlation Analysis between DOC and DON both in soil and grass shoot biomass, temperature, and soil water content for all locations.

To understand the contribution of soil enzymes to DOC and DON, we determined soil enzymes in similar fashion as described above. Specifically, we measured the enzyme activities of the soil samples collected from the urban turfs in Hong Kong and Shenzhen. Both vertical changes and age correlation were compared among all the turf sites.

1.3. Grass sampling and C analysis

Grass sampling and C content analysis followed the methods by Kong et al. (2014). Briefly, aboveground grass shoots (25 × 15 cm^2) were collected from all turfs, and oven dried at 105°C for 48 hr to obtain the dry-weight biomass. Grass samples were cut and analyzed with a TOC analyzer to determine the concentrations of TC, IC and OC, which were used to calculate the amount of grass C stock by multiplying

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